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HUNTSVILLE, ALABAMA

A SURVEY OF THE EUROPEAN SPACE PROGRAM

By

James P. Gardner

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ABSTRACT

This report presents the history and recent progress of a unified effort of several major European nations to undertake the exploration of space. Emphasis is placed on the development of a Blue Streak-based carrier vehicle that probably will play the leading role in the European space program. It is evident that this program is rapidly gathering momentum and should the trend continue, will provide the world community with many valuable contributions.

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Science & Technology Section

Space Systems Information Branch

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SUMMARY

This report presents the history and recent progress of a unified effort of several major European nations to undertake the exploration of space. Emphasis is pl'aced on the development of a Blue Streak-based carrier vehicle that probably will play the leading role in the European space program. It is evident that this program is rapidly gathering momentum and should the trend continue, will provide the world community with many valuable contributions.

INTRODUCTION

In a paper presented at the European Symposium on Space Technology in London during June 1961, Member of Parliament David Price made the following statement:

"A European program of space research would bring direct benefits to European engineering and thus it is important for us to recognize that space engineering is a new kind of engineering. It does not just consist of a hotted-up version of old engineering techniques applied to a new pattern.

"A few years ago the engineering problems of space exploration were not clearly defined, nor were the nature of 'their solutions. As a result of recent work in the USA, we can now see clearly where space engineering is likely to lead in the early future. The areas of advance are likely to be in control, communication, and power as well as in structures and in mechanical engineering.

"I am sure that my audience would agree that space technology is a highly sophisticated, new and stimulating branch of engineering. What it can offer in new understanding, new instruments, and new processes can only be dimly seen at present. To predict its impact upon the development of engineering skill and economic well-being in our compact and complex industrial continent, we must rely on historical parallels and our understanding of the development of Europe's industrial strength."

The above statment is evidence of one European nation's realization of the importance of keeping up with the technology of the world community. This realization is the primary force behind the evolution of the European'space program, embryonic though it may be, as it exists today.

HISTORY

In September 1960 the Consultative Assembly of the Council of Europe, representing the parliaments of 15 European countries, passed a five-point resolution recommending that the Committee of Ministers study, as a matter of urgent policy, the possibilities of organizing and undertaking a joint European space program.

In the meantime scientists from 10 European countries had been meeting for the purpose of considering the possibility of European cooperation in space research. Following subsequent meetings in London and Paris, an Intergovernmental Conference on Space Research was held in Geneva where an agreement was signed to set up a Preparatory Commission for a European Space Research Organization (ESRO). This commission is directed by Sir Harrie Massey, head of the department of physics at University College, London.* This organization, expected to start functioning in October 1962, will establish a 300-man research center where satellite instrumentation will be manufactured but not space carrier vehicles.

CURRENT PLANS

Current plans call for the development of a carrier vehicle proposed by the European Satellite Launching Organization (ESLO). It would be a 95-foot,three-stage, satellite carrier vehicle (FIGURE 1) based on the English Blue Streak IRBM, a French second stage, and a yet-to-be-designed third stage.** Other participating countries may act as subcontractors for the development of some flight hardware as well as ground support equipment.

THE PROPOSED LAUNCH VEHICLE

The majority of today's satellites are boosted into space by vehicles originally conceived and constructed as military ballistic missiles. The Blue Streak, which soon will boost European satellites into orbit, is no exception, The original requirements established in 1955 called for the delivery of a thermonuclear warhead to a range of 2500 to 3700 miles.

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*He is also chairman of the British National Committee for Space Research and author of Theory of Atomic Collisions and Negative Ions. During World War II, Sir Harrie worked with E.O. Lawrence on the electromagnetic separation of uranium for the Manhattan Project.

**On March 29, 1962, Britain, France, West Germany, and Italy signed an agreement to use the Blue Streak vehicle for a first launch in 1965.

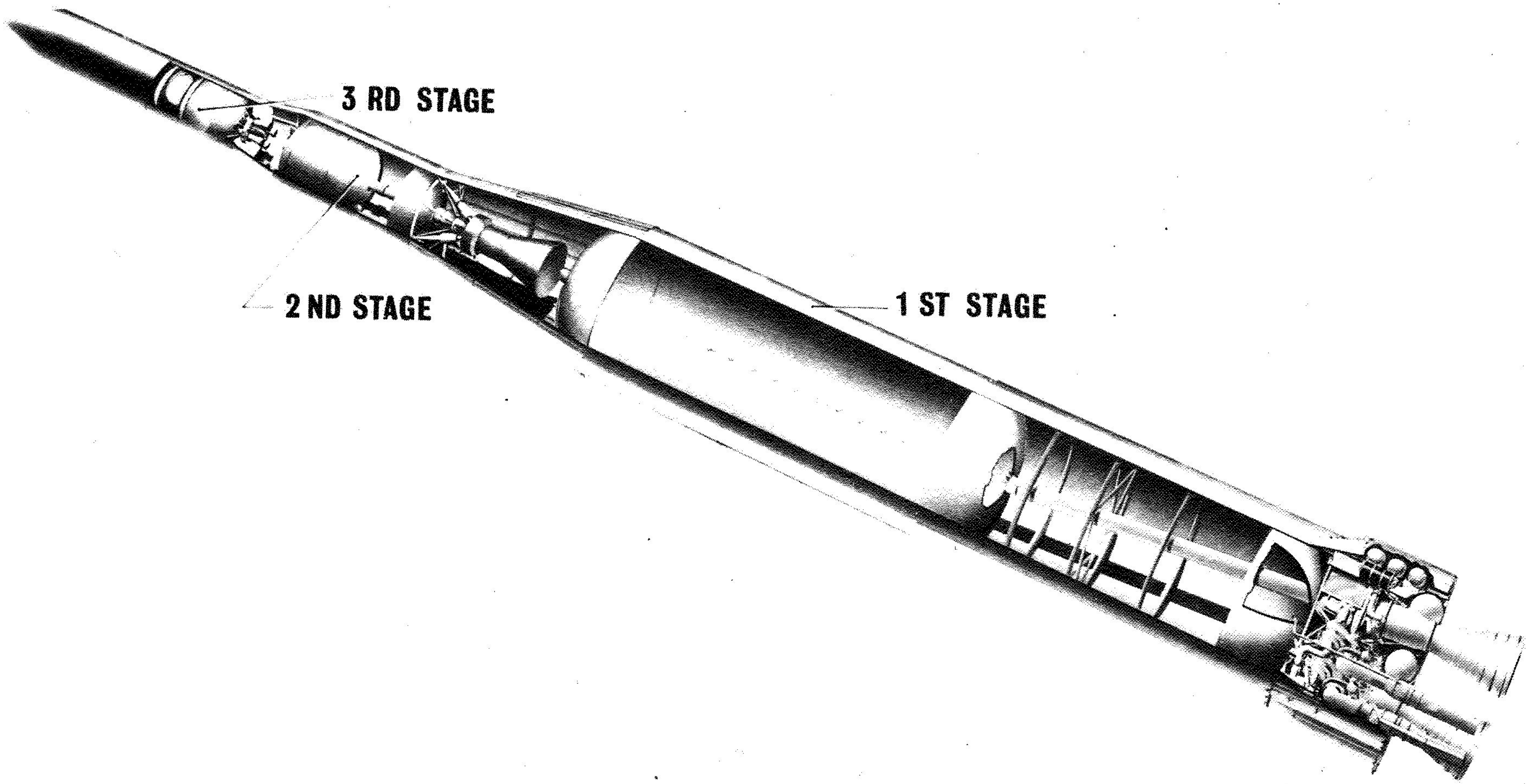

FIGURE 1. PROPOSED EUROPEAN SPACE CARRIER VEHICLE BASED ON BLUE STREAK FIRST STAGE. (COURTESY DE HAVILAND AIRCRAFT CO., LTD.)

The de Haviland Propellers Company, Ltd. was selected as prime contractor, and Rolls Royce Ltd. was chosen to manufacture the rocket engines under a license agreement with North American Aviation. The guidance system was to be developed by Sperry Gyroscope. The missle that evolved, the Blue Streak, was built according to typical monocoque techniques and employed an inertial system for guidance. The proposed space carrier vehicle, however, would have a command guidance to reduce the weight associated with inertial guidance. Engines and propellants are similar to those used in U S ICBM's; however, the Blue Streak is equipped with two NAA S3-type engines in order to incvease the range.

Because of the questionable advantages of expensive military rocket development, the British Parliament decided on April **13,** 1960 to cancel the Blue Streak project for military usage. However, complete cancellation would have meant writing off a $200 million investment; as a result, the British Government then surveyed possibilities of space exploration utilizing Blue Streak. The original proposal for the second stage was for a developed version of the Black Knight ballistic research vehicle. Several possibilities for a third stage, both liquid and solid, were considered. Two configurations based on these early proposals are shown in FIGURE **2.** For economic reasons, however, the British decided to abandon the idea of a domestic carrier vehicle development program.

Subsequently, the British and French governments invited West Germany, Italy, Spain, Sweden, Belgium, Netherlands, Switzerland, Norway, Denmark, and Austria to a Conference on a Satellite Carrier Rocket at Strasbourg on January 30, 1961, Details of the project were revealed and suggestions were made relating to cost and labor. Following is a general description of the proposed vehicle.

THE FIRST STAGE

Blue Streak is basically a 10-foot diameter cylinder with an over-all length of over 60 feet, as shown in FIGURES **3** and ***4.*** The total weight including propellant is about 90 tons. Two functionally inde-pendent Rolls Royce RZ. **2** rocket engines (FIGURE 5) combine to produce a thrust of 300,000 lb. By gimballing the engines, the vehicle can be controlled in yaw, pitch, and roll. Each engine unit weighs 1500 lb and has its own propellant feed and control system and is equipped with a turbopump that feeds propellants to a regeneratively cooled thrust chamber. The thrust chamber (FIGURE 6) is of tubular-walled construction; the total flow of kerosene traverses the chamber walls before entering the combustion zone. The propellant feed system at ignition is shown schematically in FIGURE 7.

Propellant pumps (FIGURE 8) are driven by a turbine through a simple spur reduction gear; a separate gas generator (FIGURE 9), burning a fuel-rich propellant mixture, supplies the turbine.

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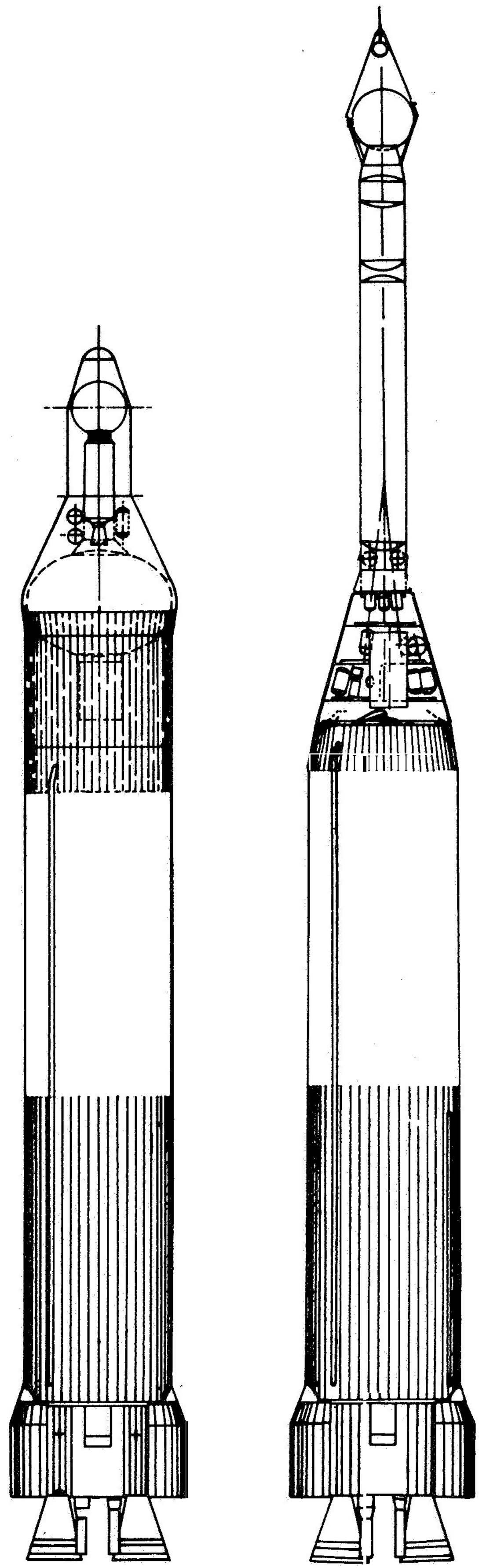

FIGURE 2. EARLY PROPOSED SPACE CARRIER VEHICLES BASED ON BLUE STREAK FIRST STAGE AND BLACK KNIGHT SECOND STAGE.

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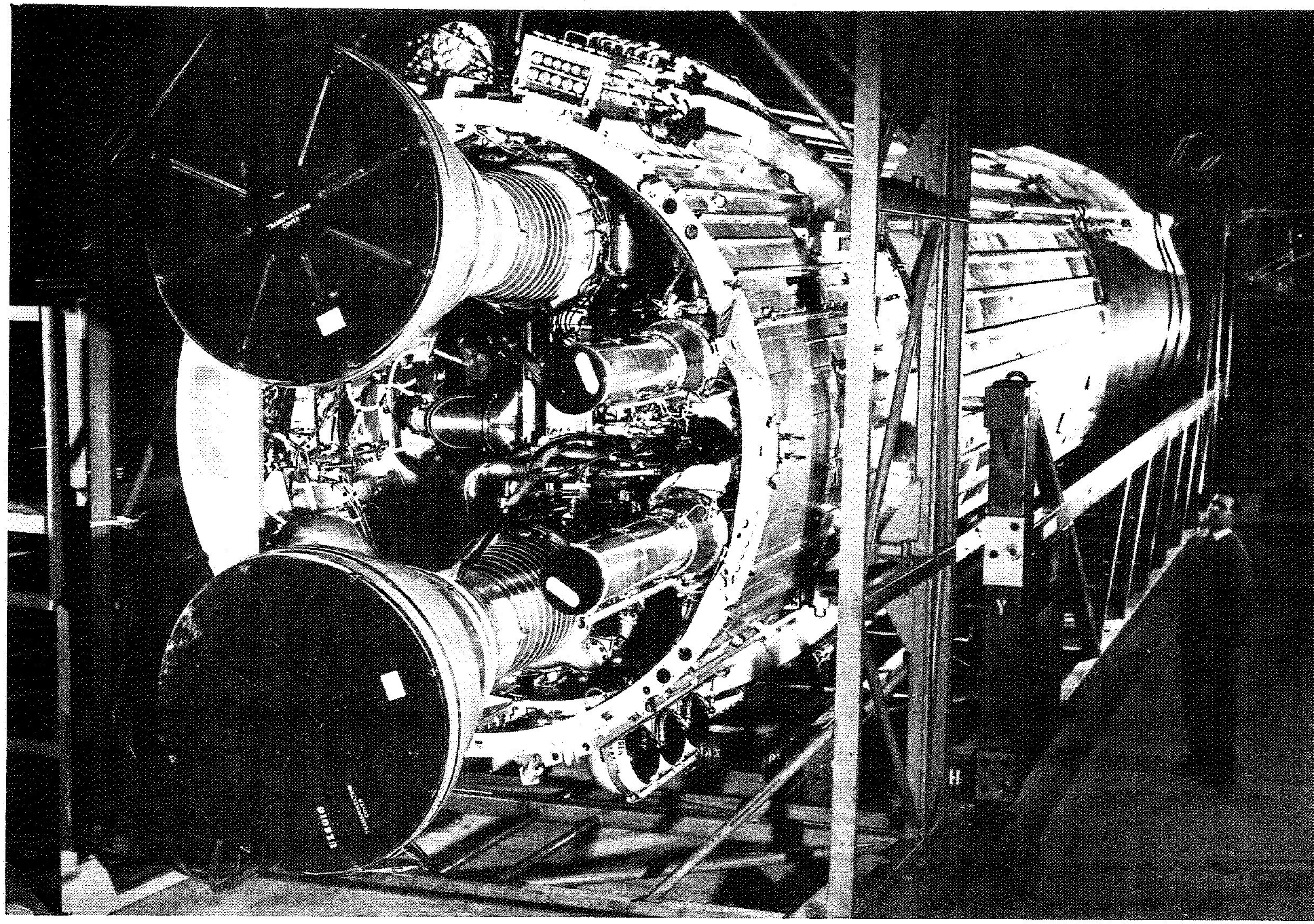


FIGURE 3. BLUE STREAK VEHICLE. (COURTESY DE HAVILAND AIRCRAFT CO, LTD.)

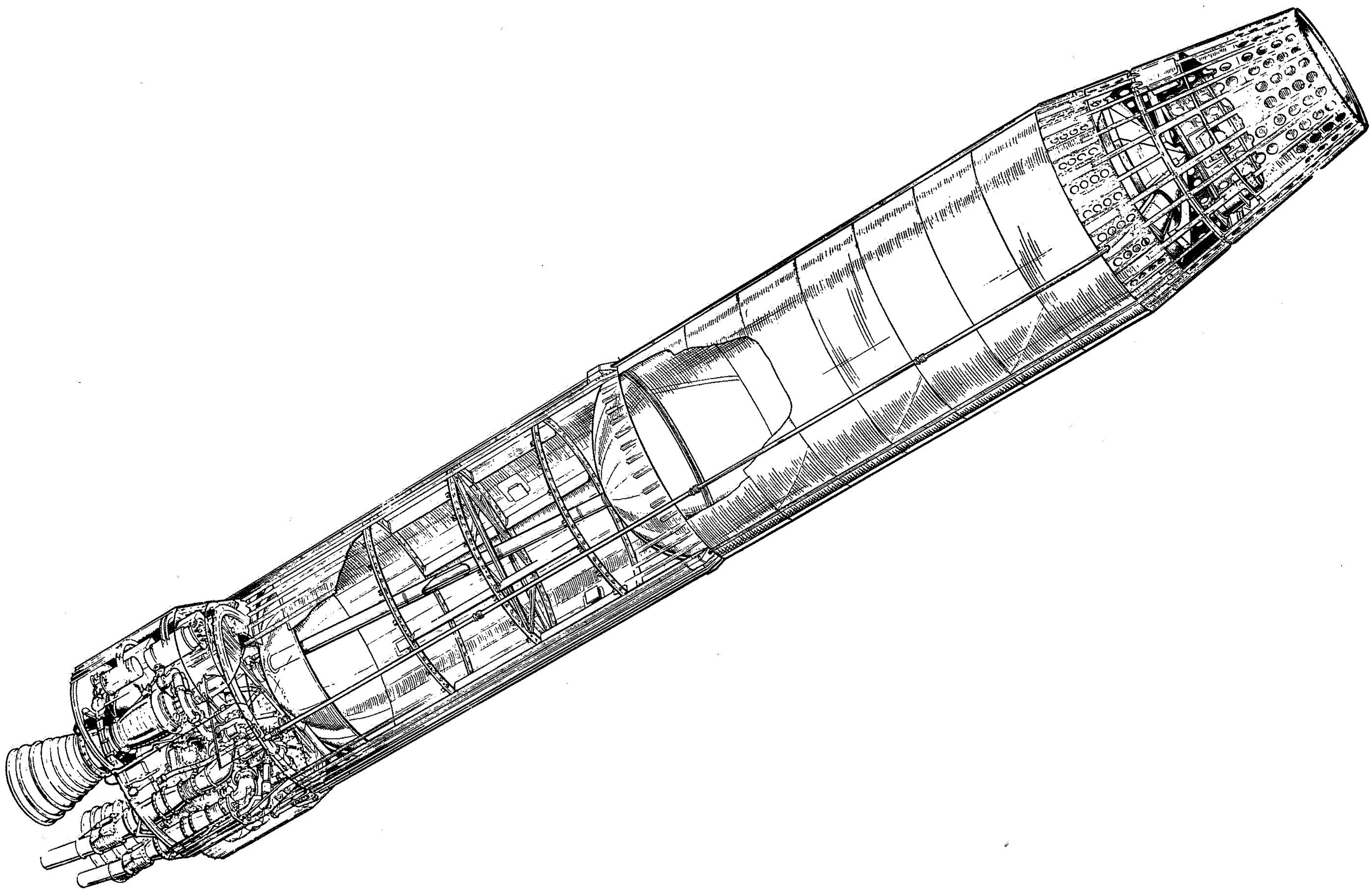


FIGURE 4. CUTAWAY VIEW OF BLUE STREAK. (COURTESY DE HAVILAND AIRCRAFT CO., LTD.)

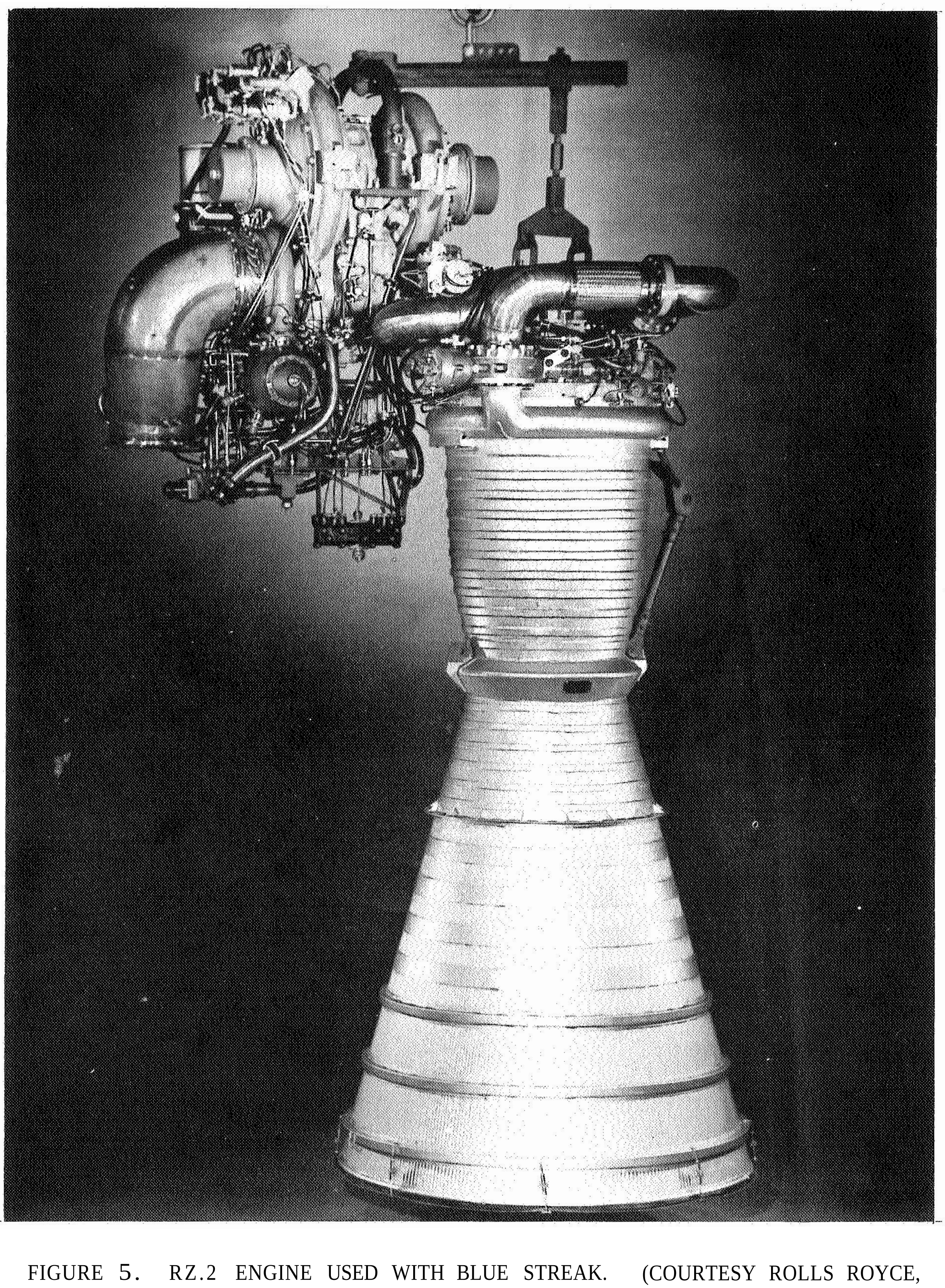


FIGURE 5. RZ.2 ENGINE USED WITH BLUE STREAK. (COURTESY ROLLS ROYCE, LTD.)

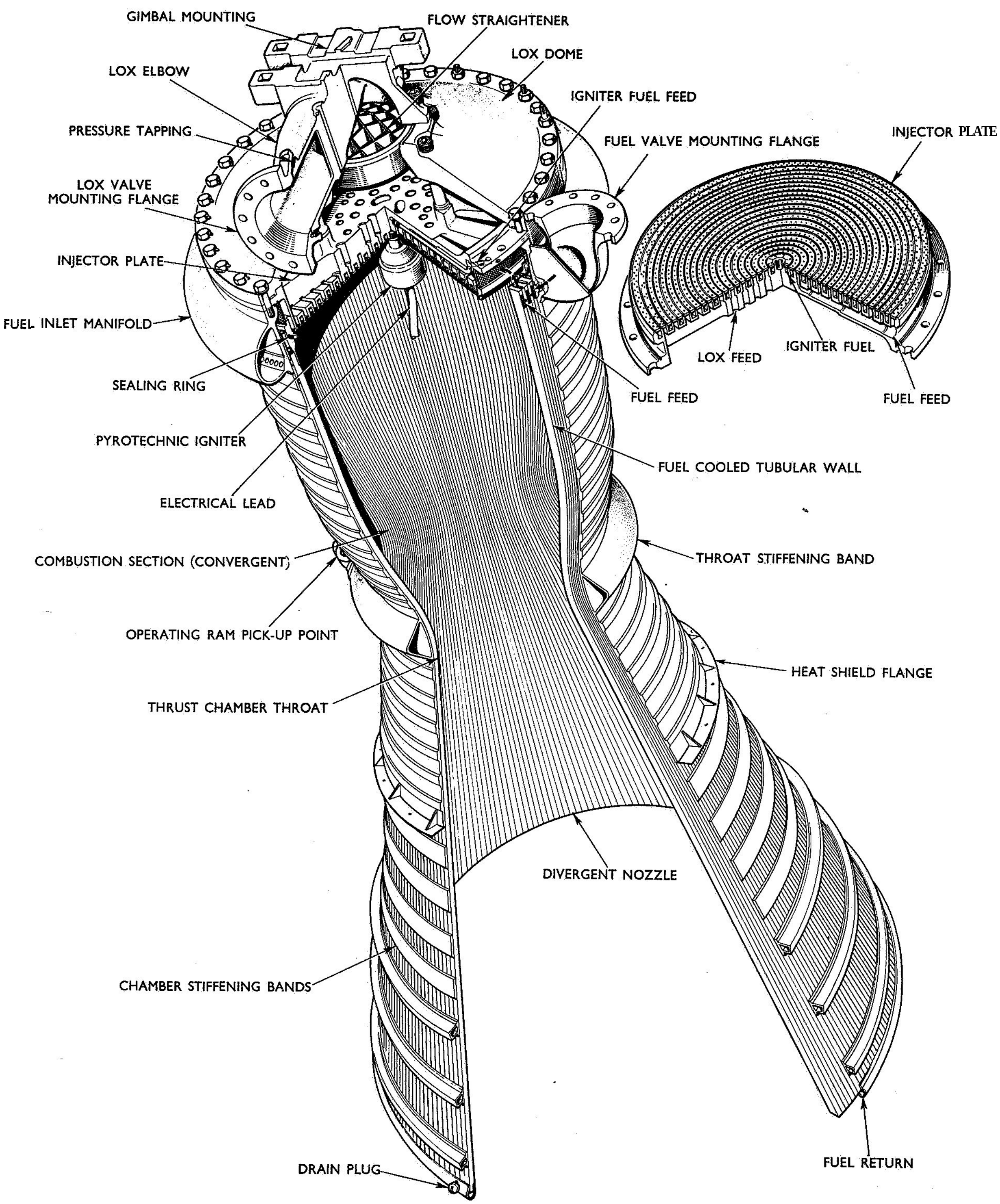


FIGURE 6. CUTAWAY VIEW OF **THRUST** CHAMBER OF RZ.2 ENGINE. (COURTESY **ROLLS** ROYCE, **LTD.)**

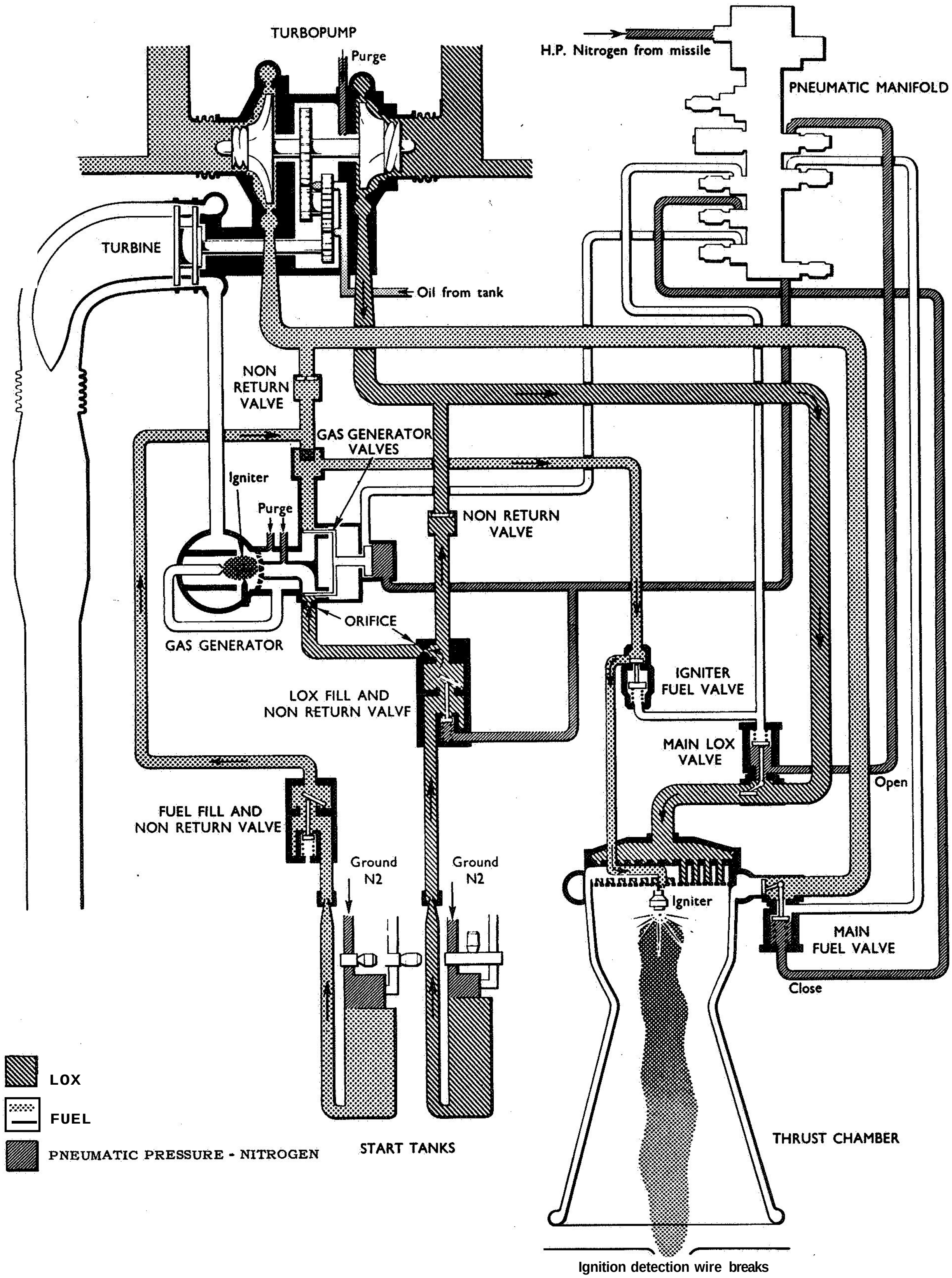


FIGURE 7. PROPELLANT FEED SYSTEM OF RZ.2 ENGINE AT IGNITION. (COURTESY ROLLS ROYCE, LTD.)

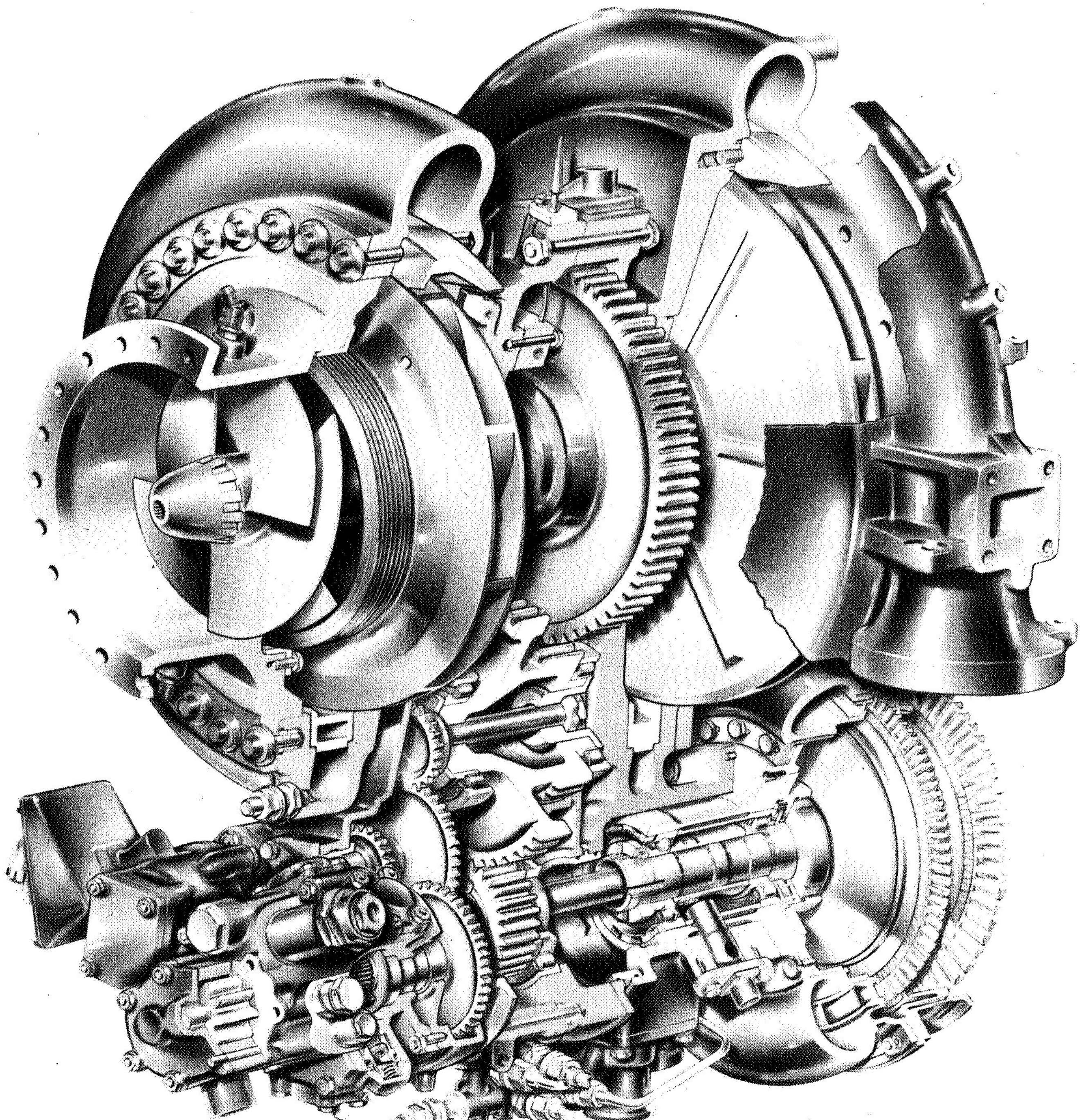


FIGURE 8. TURBOPUMP FOR RZ.2 ENGINE. (COURTSEY ROLLS ROYCE, LTD.)

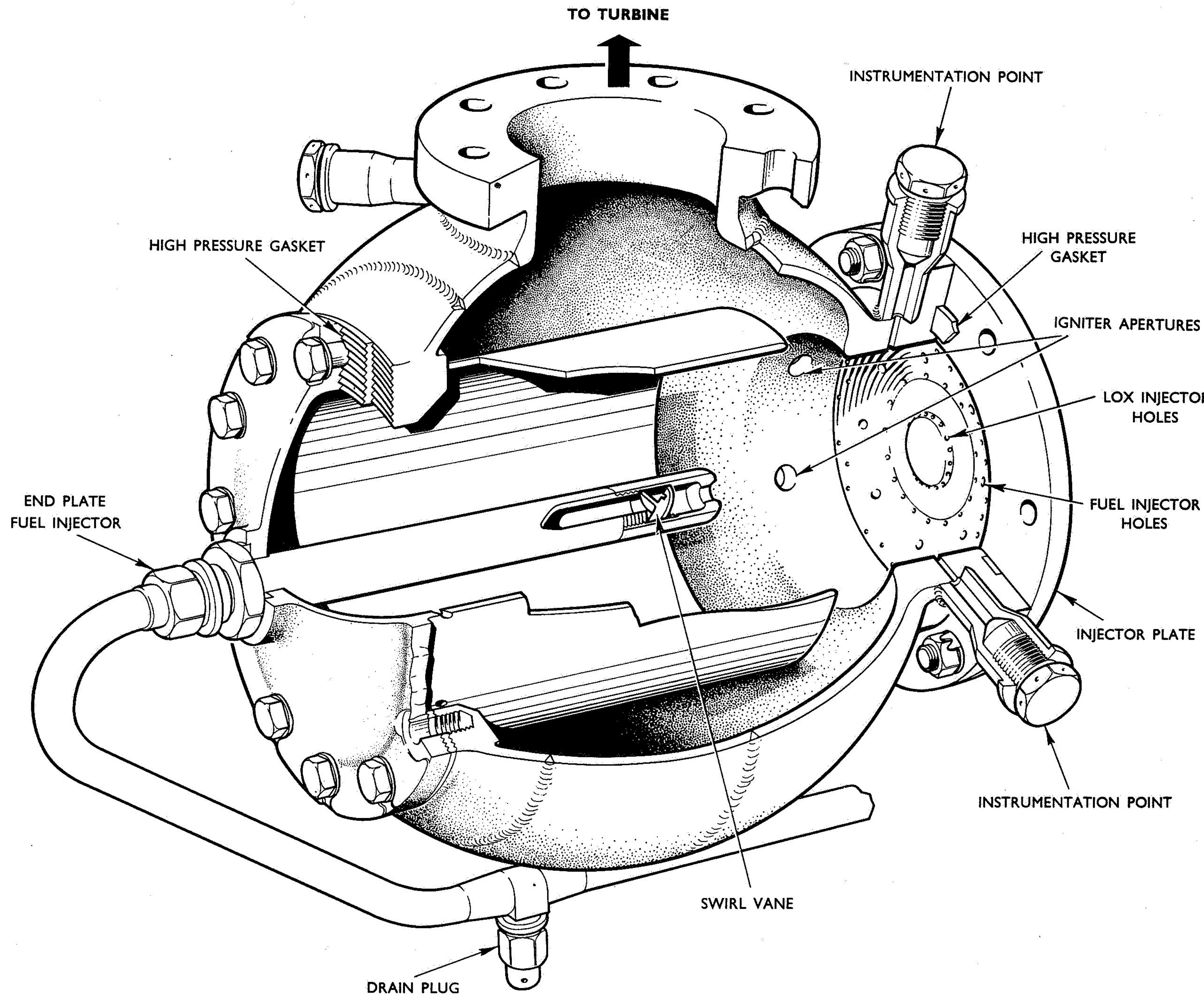


FIGURE 9. GAS GENERATOR FOR RZ.2 ENGINE. (COURTESY ROLLS ROYCE, LTD.)

The fuel-rich mixture keeps the temperature of combustion gases at an acceptable level of about 650°C. The mixture (o/f) ratio used in the gas generator is about 0.35/1 by weight.

The complete two-engine propulsion system, as shown in FIGURE 10, is designated RZ. 12.

Using the Blue Streak as the first stage of a 3-stage vehicle weighing some 230,000 lb, the vehicle would rise vertically for 20 seconds and climb steadily to 2000 feet. At this point, a gradual pitching over to the desired trajectory angle of about 30 degrees with the horizontal would begin. Upon attaining the 30-degree tilt angle, the vehicle's speed would be 2500 mph at a height of nearly 18 miles. Acceleration along this path would continue until burnout, which should occur at a speed of 8500 mph. The calculated time from launch to first stage burnout would be about 160 seconds at an altitude of 50 miles and a range of 80 miles. At engine cutoff, ignition of the second stage would take place. The Blue Streak first stage would then separate from the second stage and eventually impact on the Earth approximately 400 miles downrange.

THE SECOND STAGE

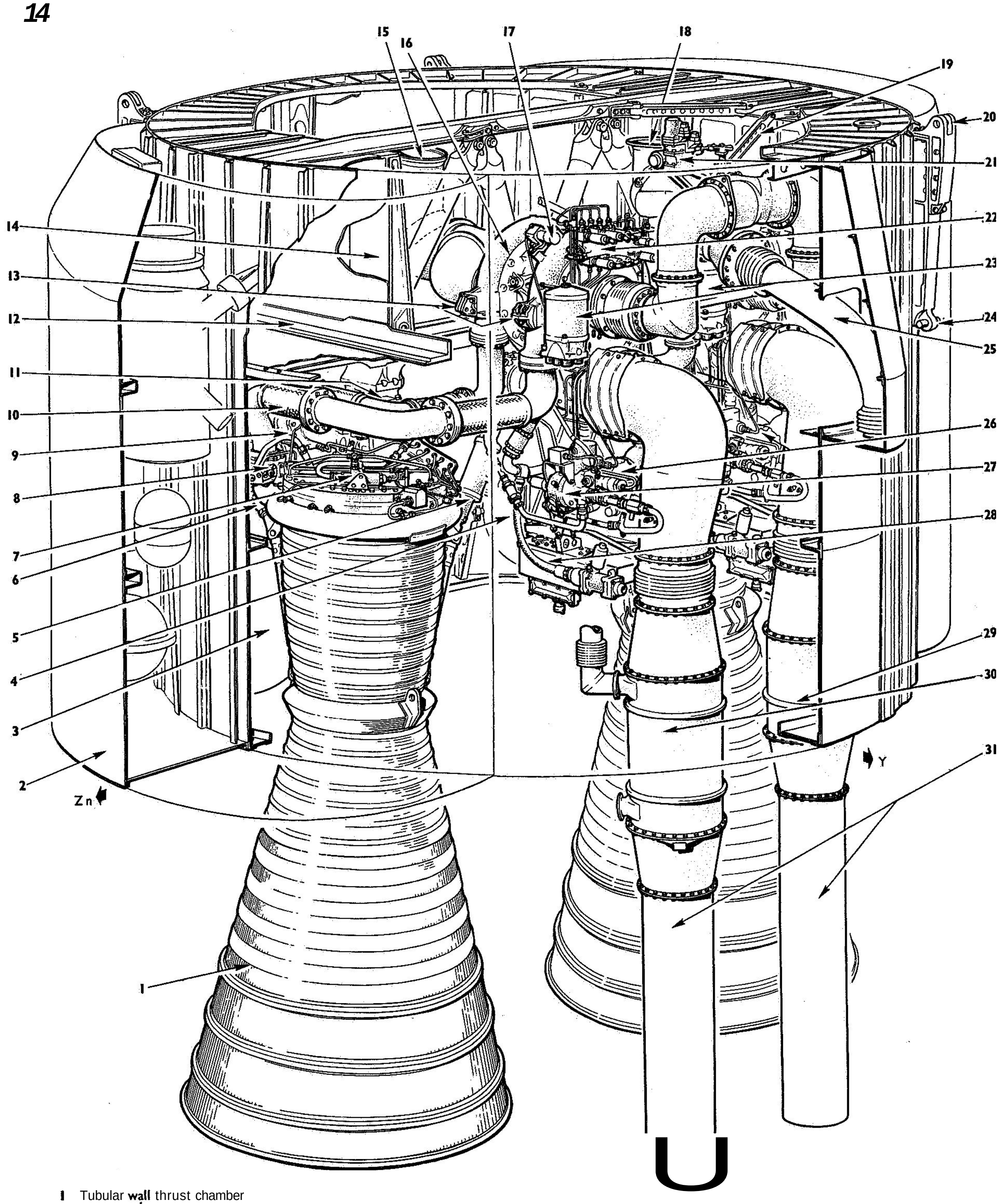
The French second stage, developed especially, but using experience gained in the Veronique sounding rocket program, would increase the speed from 8500 mph to 14,500 mph. This speed would be reached some 250 miles downrange at an altitude of 105 miles. Here, third stage ignition would occur and the second stage would fall to Earth, impacting approximately 3000 miles from the launch point.

THE THIRD STAGE

The third stage, while not yet designed, may burn either conventional chemical propellants or high energy propellants. There is also a possibility that it will have a restart capability. It could also have a thrust duration up to 10 minutes and a sea level thrust between 1000 and 5000 lb. At burnout of the second stage, the third stage would ignite and boost the velocity to 17,000 or 24,000 mph, depending on the mission. The stage will probably be designed and manufactured by West Germany with the assistance and participation of several other European countries.

VEHICLE DATA

Data on the proposed space carrier vehicle are listed in Table I.



1 Tubular wall thrust chamber
2 Equipment fairing
3 Engine oil tank
4 Liquid nitrogen bottle
5 Pitch control ram
6 Yaw control ram
7 Igniter fuel valve
8 Main fuel valve
9 Main lox valve
10 Propellant flexible
11 Gimbal mounting
12 Main motor beam
13 Pump mounting
14 Thrust bracket
15 Lox inlet to pumps
16 Lox pump
17 Reference pressure loader
18 Fuel inlet to pumps
19 Turbopump vee frame
20 Attachment to tank bay
21 Fuel tank valve
22 Pneumatic manifold
23 Engine relay boxes
24 Launcher bracket
25 Main fuel probe
26 Gas generator
27 Lox regulator
28 Instrumentation box
29 Heat exchanger (nitrogen)
30 Heat exchanger (gox)
31 Turbine exhaust

FIGURE 10. RZ. 12 PROPULSION SYSTEM FOR PROPOSED EUROPEAN SPACE CARRIER VEHICLE. (COURTESY ROLLS ROYCE, LTD.)

TABLE I. PROPOSED EUROPEAN SPACE CARRIER VEHICLE

Complete 3-Stage Vehicle:	
Overall Length, ft	99.5
Total Lift-off Weight, lb	230,769
First Stage: (Blue Streak)	
Dimensions	
Length, overall, ft	61.5
Length (tank bay), ft	46
Tank, diameter, in.	120
Propulsion Bay, diameter, in.	108
Weights	
Stage, loaded, lb	207,597
Propellants, lb	193,892
Burnt, lb	13,687
Propulsion	
Thrust (2 engines, uprated, sea level), lb	300,000
Burning time, sec	160
Fuel	Kerosene
Oxidizer	Liquid Oxygen
Mixture ratio, oxidizer/fuel	2 25/1
I_{sp}, sec	245-289
Expansion ratio	8:1
Chamber pressure, psi	544

Engine Gimballing: limits of thrust-chamber movement, anywhere within pyramid of 14 deg included angle; maximum programmed turnover rate, 0.7 deg/sec; hydraulic system pressure, 3500 psi.

Liquid Oxygen System: tank capacity, 2000 ft3 usable (12,000 imp gal or 60.8 long tons); tank pressurization, 5 psi empty, 26 psi full; pressurization by oxygen gas from B heat exchanger.

Kerosene System: tank capacity, 1250 ft^3 usable (7700 imp gal or 26.3 long tons); tank pressurization, 2.5 psi empty, 11.75 psi full; pressurization by nitrogen from heat exchanger A.

Gas Generator: working-fluid mixture strength, oxidizer/fuel 0.35/1; mass-flow rate, 2.6 lb/sec lox and 7.4 lb/sec kerosene; delivery temperature to turbine, $650^\circ C$, 425 psi.

Turbopump: turbine speed, at present engine rating, 29,300 rpm; output, 2470 to 2500 shaft hp; gearbox reduction ratio, 4.88: 1; pump shaft speed, 5987 rpm at present engine rating; lox impeller diameter, 11 in; lox-pump delivery, 385 lb/sec at 787 psi; kerosene impeller diameter, 12.75 in.; kerosene-pump delivery, 178 lb/sec at 753 psi.

TABLE I. PROPOSED EUROPEAN SPACE CARRIER VEHICLE (Cont'd)

Ancillary Systems: liquid nitrogen sphere, 145 lb capacity; liquid nitrogen pressure to heat exchanger, 120 psi; gaseous nitrogen spheres, each 1037 $in.^3$ charge pressure, 3000 psi; minimum working pressure, 1000 psi; lox pressurization circuit bleeds lox at about 700 psi at 2.5 lb/sec and delivers gas at 180°C at 60-70 psi; lube-oil, 20 gal delivered at 750 psi at 6 gal/min total.

Second Stage: (French design in process; all figures estimated)

Dimensions	
Length, overall, ft	22
Diameter, in.	72
Weights	
Stage, loaded, lb	18,150
Propellants, lb	15,432
Burnt, lb	2718
Propulsion	
Thrust (vacuum), lb	68,000
Burning time, sec	61
Fuel	N_2O_4
I_{sp}, sec	260

Third Stage: (not yet designed; all figures estimated)

Dimensions	
Length, ft	20
Diameter, in.	54
Weights	
Stage, loaded (including 200-lb payload), lb	5040
Propellants (lb)	4300
Burnt (lb)	700
Propulsion	
Thrust, lb	1000-5000

PAYLOADS AND MISSIONS

Assuming that no liquid hydrogen-liquid oxygen upper stages are used, the proposed carrier vehicle would have the capability of placing 2000 lb into a 300-nautical-mile orbit, 500 lb into a 500-mile circular orbit, or 900 lb into an orbit with a perigee of 300 miles and an apogee of 7000 miles. Also, a 300-lb payload could be placed into a highly elliptical orbit with a 300-mile perigee and a 100,000-mile apogee. Such a flexibility in payloads and orbital altitudes lends itself well to the variety of satellites planned by the ESRO. These include astronomical, meteorological, geophysical, and other scientific satellites, in 1966 as well as an active communications satellite (such as shown in FIGURE 11), probably not in a 24-hour orbit.

The initial phase of launches would conclude with automatic observatories in lunar orbits in the late 1960's. The ESRO at present does not intend to put a man into space, and appears to be planning to complement the scientific satellite work of the US and USSR rather than compete with it. For this reason no plans are currently being made for landing payloads on the Moon. The first launches by ESRO planned for 1963, will be a series of 10 sounding rockets from the Kiurna Rocket Range now being built in Sweden. This schedule will be expanded to 65 launchings a year as the program progresses.

TESTING AND RELIABILITY

The first test firing of an RZ.2 engine took place in March 1959, and the RZ.12 combination was first test fired at Spadeadam Rocket Propulsion Establishment in March 1960, as shown in FIGURE 12. A summary of test experience both on the RZ.2 and the RZ.12 is given in Table II. The failure to start or reach scheduled duration may at first appear high for the RZ.2, but many of the failures were caused by malfunctions in the complex test facility rather than in the engine under test. Running reliability for the RZ.2 is currently 96 percent, and start reliability is 92 percent. This gives an overall reliability of 88.4 percent. While the RZ.12 has a 100 percent reliability in running, 95 percent in start, and 95 percent overall, it must be kept in mind that a relatively small number have been tested.

Component testing also paralleled development of the RZ.2 engine. By June 1961 some 530 tests totalling 35,000 seconds were logged by the turbopump. The gas generator had logged 83,000 seconds in 1600 tests. Component testing is usually carried out at the manufacturer's test facilities, while static firings of the vehicle take place at Spadeadam Rocket Propulsion Establishment near Carlisle (FIGURE 13).

Testing to date has experienced a few problems and failures. In one test, diffuser vane fretting caused an explosion in a liquid oxygen pump, but redesign eliminated the problem. In another test a bad weld in one engine caused a slow start and resulted in the thrust chamber's being blown off.

TABLE 11. TOTAL TEST EXPERIENCE THROUGH MAY 1961

	RZ. 2	RZ. 12
Tests of scheduled duration	317	48
Successful starts (at least 0.5 sec mainstage)	365	51
Starting attempts	474	55
Runs of 150 sec or greater	8	8
Total duration, sec	7733	2532

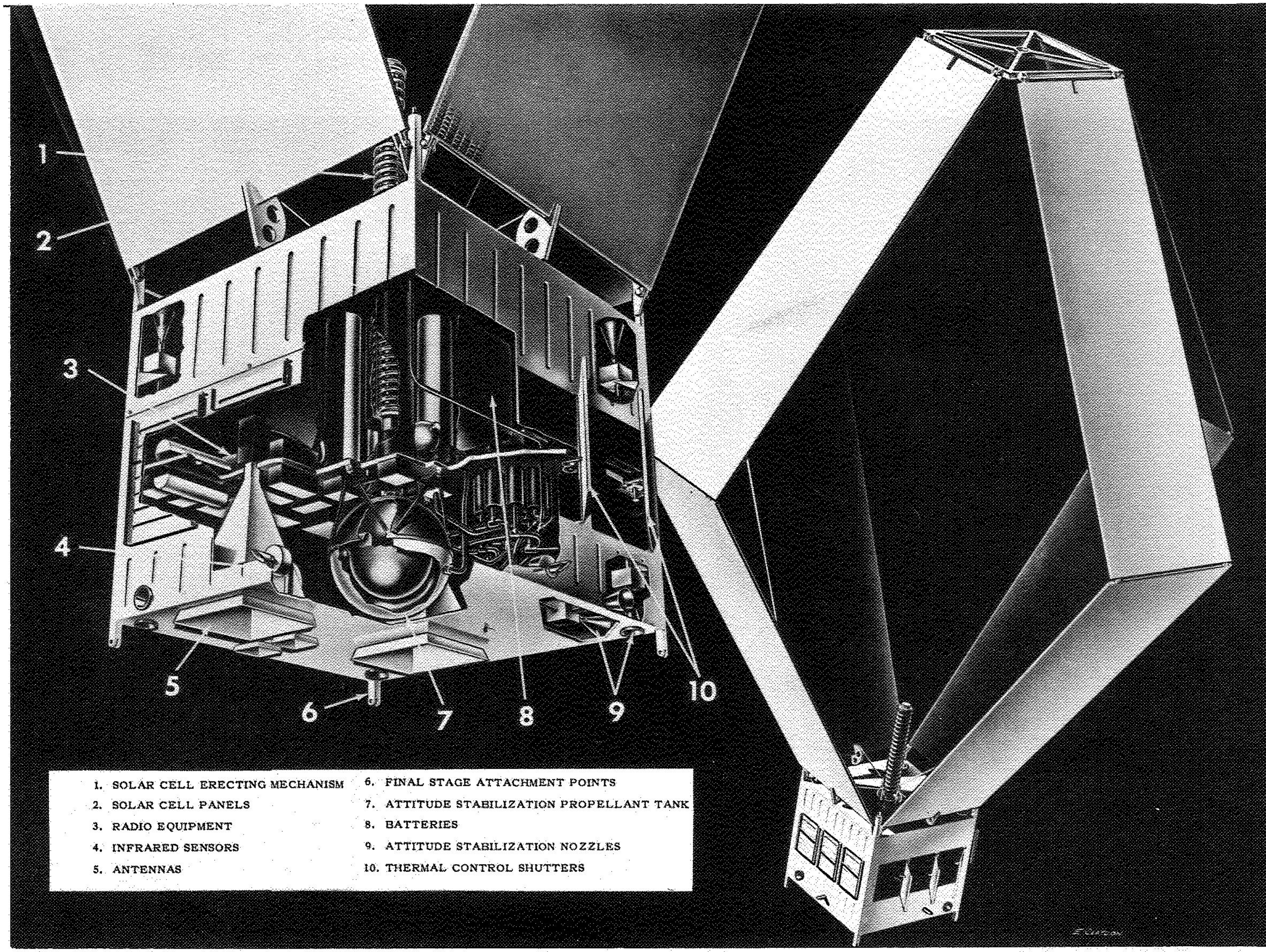


FIGURE 11. PROPOSED COMMUNICATIONS SATELLITE FOR EUROPEAN SPACE CARRIER VEHICLE. (REPRINTED BY PERMISSION OF HAWKER SIDDELEY AVIATION, LTD.)

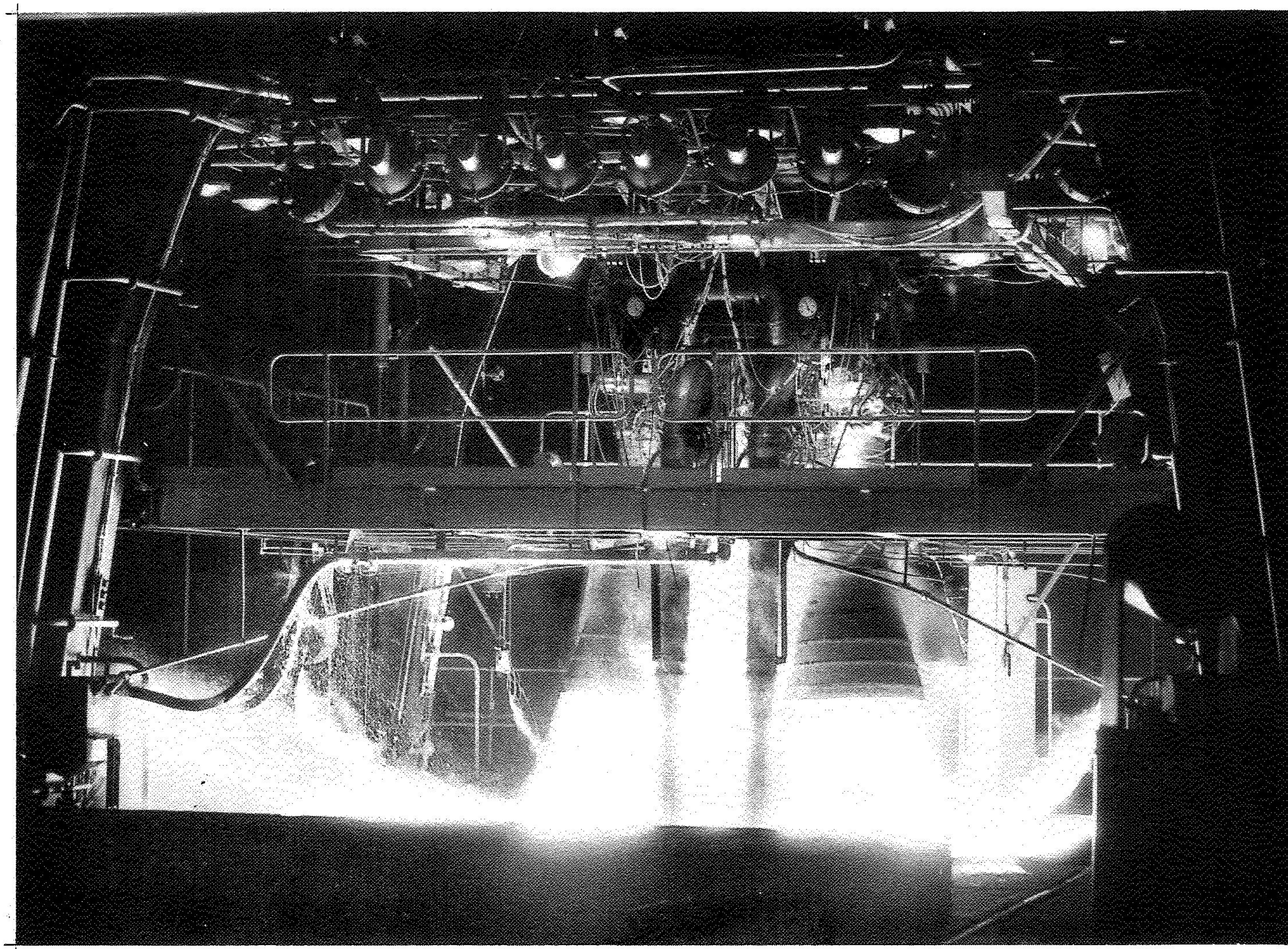


FIGURE 12. STATIC FIRING OF RZ.12 PROPULSION SYSTEM AT SPADEADAM ROCKET ESTABLISHMENT. (COURTESY ROLLS ROYCE, LTD.)

FIGURE 13. STATIC TEST STAND FOR BLUE STREAK AT SPADEADAM ROCKET ESTABLISHMENT. (COURTESY SPADEADAM ROCKET ESTABLISHMENT)

In general, it has been found that techniques in thrust chamber and injector plate manufacturing are critical. All in all, flight engines are now being delivered that perform to within 1.5 percent of specification thrust.

Second stage component testing and engine static firing will be done at the Laboratoire de Recherches Balistiques et Aérodynamiques, at Vernon, near Paris. The Establissement Aéronautique at Toulouse is equipped for structural testing, while facilities at Cannes are available for environmental testing. Flight testing of the stage will undoubtedly be made at the French rocket range at Colomb-Béchar in North Africa.

LAUNCHING SITES

Since the Blue Streak-based vehicle is to be used for ESRO launches they will, in all probability, be made from the Woomera Rocket Range in Australia beginning with test firings in 1965. A special Blue Streak launching pad is available at Lake Hart, South Australia. It has a novel feature in that no flame deflector is necessary since the launcher is situated over the side of a sheer cliff.

The launcher is mounted on a system of bogies that ride on a circular track; thus it can be oriented to any firing angle. Once the proper firing angle is established, the bogies are retracted and the launcher is clamped to the track.

Other facilities at the launch site include optical and radar tracking, range safety instrumentation, and communications equipment as well as the usual ground support equipment and blockhouse.

A typical trajectory of a launch from this position is shown in FIGURE 14.

The French rocket range at Colomb-Béchar would probably be a more desirable launching facility since it is closer to the Equator. But the cost, a prime factor in the whole European space program, of installing Blue Streak ground support equipment and launch facilities probably rules out the French site, especially since Woomera is already equipped for Blue Streak launchings.

FUTURE POSSIBILITIES

As L. R. Shepherd, past president of the British Interplanetary Society observes, it is perhaps an advantage, from the standpoint of world progress that other European nations, individually, are incapable of competing with the US and Russia in the space race. As a result, a situation is created in which if other peoples wish to participate in the great adventure of the exploration of outer space, they must lay aside purely national ambitions and join in an enterprise in which the scientific, technological, and commercial rewards are fully shared.

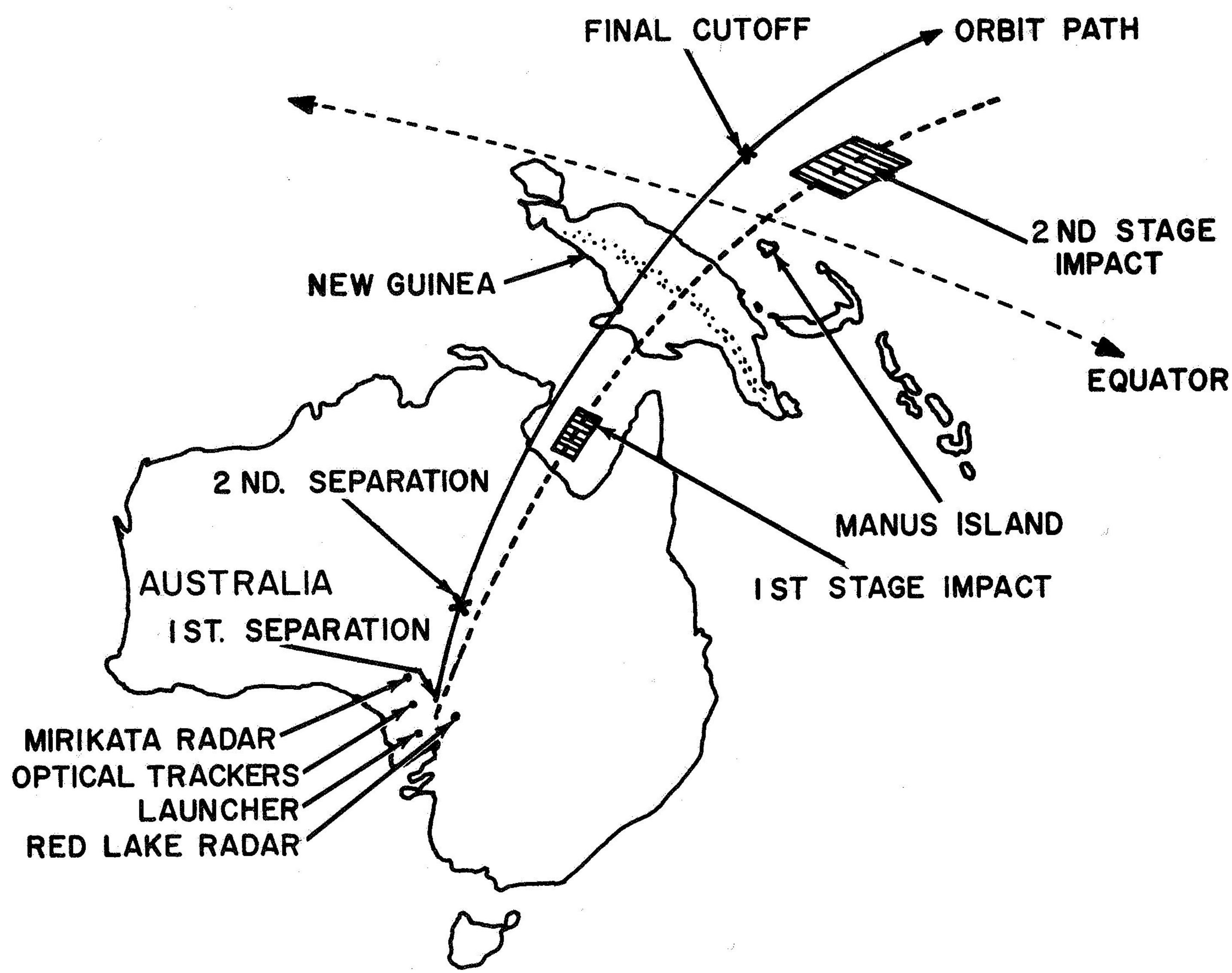


FIGURE 14. TYPICAL TRAJECTORY ASSUMING LAUNCH FROM WOOMERA RANGE IN AUSTRALIA.

Recent establishment of a National Center for Space Research (CNES) in France and an Institute of Space Research in West Germany is indicative of the increased interest upon the part of these individual nations. France alone may budget as much as **$120** million during each of the next five years in which she is an active participant in the European Space Program. In addition, the 1962 budget of the German Federal Government includes about $15,000,000 for space research, an area now the responsibility of the Federal Ministry of Atomic Energy. The European Launcher Development Organization is expecting to receive $7,500,000 and the European Research Organization $2,500,000. The remaining $5,000,000 may be given to the Society for Space Research (Gesellschaft fur Weltraumforschung).

Assuming cooperation among all members of the ESRO, a 10-year space program running to some $140,000,000 a year could be supported. Such a proposal was made in June 1961 by the British Interplanetary Society. In looking toward the next decade in space, L.R. Shepherd suggested, while making the proposal to the European Symposium on Space Technology in London, that the ESRO could economize by investigating the use of high-energy upper stages, recoverable first stages, and the use of solid propellant first stages.

Specifically, the British Interplanetary Society proposed the following schedule between 1961 and 1971.

A. VEHICLES

Phase 1 booster based on Blue Streak.

Phase 1A vehicle with Blue Streak booster and higher energy upper stages.

Phase 2 launch vehicle with possible clustered-design first stage producing 1,000,000 lb of thrust (payload capability: 20,000 lb in low Earth orbit).

Program of development of a series of interchangeable upper stages concurrent with the development of the large boost vehicles.

B. PAYLOADS

Scientific satellites utilizing Phase 1 and Phase 1A vehicles.

Soft-landing lunar payload with Phase 1A vehicle.

Close orbit and 24-hour orbital communications satellites with Phase 1 and Phase 1A vehicles.

Manned capsule for suborbital flight using Phase 1 vehicle.

C. RESEARCH AND DEVELOPMENT

Long term research, especially in propulsion, that could form the basis for a second 10-year program.

CONCLUSIONS

It is evident that most of the free nations of Europe are more interested in an active space program in which they can participate more fully than they are in the limited international space programs of the US. They appear willing to fund a modest program based initially on a space carrier vehicle derived from the Blue Streak,

Initial space activities will probably consist of scientific payloads orbiting Earth and gathering physical data similar to that of the Explorers, Discoverers, and Sputniks. Since the venture will be a cooperative one, the data will probably be widely distributed and shared with non-European nations. Interest also seems strong in an active communications satellite.

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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